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VOLUME VARIATION OF BOTTLED FOODS.

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PURPOSE OF INVESTIGATION.

The amount of variation which occurs in the volume of bottled foods packed under conditions of "good commercial practice" is often the subject of controversy among the bottler, the food official, and the bottle manufacturer. The Bureau of Chemistry has made a number of investigations on this subject. Some of these investigations have been somewhat disconnected, but the gaps existing in the information thus obtained have been filled in, so far as possible, by supplementary investigations. The prevalence of various methods of packing bottled foods, prevalence of the various types of bottles used for foods, prevalence of the different types of bottles manufactured, types of filling machines, methods of manufacture, commercial methods of purchasing and testing bottles, variations in capacity of bottles, variations in volume of contents of bottles of food, and allied subjects have been studied to determine the difficulties involved in packing bottled foods with a uniform quantity of contents. Precaution has been taken to observe the obligations of the bottler, the bottle manufacturer, and the food official to the consumer.

Because the Net Weight Amendment to the Federal Food and Drugs Act and many State laws require that food in package form bear a statement of the quantity of contents, the obligation of the food official to the consumer includes the promotion of the delivery of bottles of food which vary as little as possible from the stated quantity of contents when the possibilities of good commercial practice are taken into consideration. The obligation of the bottler to the consumer calls for an effort to deliver bottled food products, such as flavoring extracts, mineral waters, carbonated and uncarbonated beverages, molasses, honey, maple sirup, vinegar, olive oil, essential oils, table oils, catsup, and salad dressing, which are as uniform in quantity of contents as is commercially practicable. The bottle manufacturer, therefore, is under direct obligation to the bottler and indirect obligation to the consumer to furnish bottles which are as uniform in capacity as it is commercially possible to make them.

It is the purpose of this bulletin to describe a commercial method of bottling which may be considered "good," to calculate maximum variations in the volume of bottled liquids used as foods when packed in accordance with specified good commercial practice, and to present data showing that the calculated maximum variations of the good commercial practice outlined can be met by the bottler.

The results of the investigation here reported are intended to be applicable to liquid foods only.

SOME CAUSES OF VARIATION IN VOLUME OF FOOD IN BOTTLES.

The variation of the quantity of food in the bottle depends on many factors, since various types of bottles are manufactured by various methods and filled by various methods. The causes of the variations are cumulative, extending far back into the history of the bottle. In order to direct attention to the relative weight of some of the causes, certain pertinent factors in bottle manufacturing, methods of bottling, and types of bottles used as food containers are mentioned

BOTTLE MANUFACTURE.

Bottles are manufactured by three processes: Hand, semiautomatic machine, and automatic machine. The processes vary in two particulars—first, the method of gathering the proper amount of glass to be blown into a bottle, and, second, the method of blowing the bottle.

Hand blowing is the oldest and simplest method of manufacture. In this process one end of the punty, a hollow tube about 6 feet long, is inserted in the molten glass and rotated until the amount of glass necessary to produce a bottle of the desired weight has been

collected. The lump of glass attached to the punty is rolled into a pear-shaped lump on an iron plate, placed in a mould, and the glass expanded to the limiting mould walls by blowing through the punty. As soon as the mass has been expanded to the limits of the mould, the punty is detached, the mould opened, and the bottle removed. The neck is then reheated and finished and the bottle placed in a cooling chamber, where the temperature is gradually reduced.

The semiautomatic machine process embodies the first attempts to apply machinery to the blowing of bottles. A stream of glass falling into the mould is cut off by scissors operated by a foot treadle. Since practically all of the glass which falls into the mould is contained in the finished bottle, its weight depends upon the judgment of the operator of the foot treadle. The molten glass is formed roughly in a blank mould by a plunger, and it is then transferred by hand to the blow mould, where it is blown by compressed air to the limits of the walls of the mould.

The automatic machine process accomplishes all steps of bottle manufacture by machinery. The amount of glass is gauged by filling a hollow mould by suction and striking off the excess glass with a knife. The weight of the glass in the bottle is that measured into the mould. After forming the neck of the bottle in this mould the blow mould is brought into position around the pencil of glass, which is expanded to the mould limits by compressed air.

In both hand and semiautomatic machine processes the weights of the bottles are controlled by the accuracies of human judgment, in the first case in properly estimating the weight of molten glass on the punty, and in the second case in properly estimating the amount of glass which drops into the mould. In the automatic machine process the weight of the bottle depends upon the amount of glass measured into the mould by machinery and does not depend upon the accuracy of human judgment. So far as the manufacturing affects the weight of the bottles there are only two processes, hand and machine, the semiautomatic machine process falling into the first class.

In all processes the mould is manufactured according to strict specifications and tests. Its cavity, which controls the exterior dimensions of the bottle, is accurately machined to previously determined dimensions, and sample bottles are blown for weight and capacity tests before it is installed. With continual use a scum accumulates in the mould, slightly diminishing its interior dimensions. After this scum has been removed a sufficient number of times, the mould's dimensions become appreciably larger, so that a new mould must be substituted for it. Much attention is given to the cleaning of the mould and to the possibility of its replacement by the bottle

manufacturer. One of the criteria for changing it is the increased weight of the bottle when bottles of a definite capacity are being blown.

To assist him in keeping the weight of the bottles as accurate as possible, the hand blower familiarizes himself with the weights of the bottles as he blows them and can at once adjust any tendencies toward overweight or underweight. In the Wage Scale and Working Rules of the Glass Bottle Blowers' Association the blower is continually cautioned to "work as close to weight given as possible." Similar precautions are taken in blowing bottles by the machine process. For the past 30 years at least (1) (6),[1] the National Glass Bottle and Vial Manufacturers' Association, composed of manufacturers, and the Glass Bottle Blowers' Association, composed of blowers, have held annual conventions, where questions pertaining to their several interests are discussed and agreements made by which each party should be governed. The limit of variation in weights which would be permitted during the ensuing year has been one of the questions decided at these meetings. This point became of special importance after the passage of the Net Weight Amendment to the Federal Food and Drugs Act, March 3, 1913, when the food officials were also consulted. The variations agreed upon and adopted in 1914 have been readopted annually without change. The manufacturer has the privilege of rejecting bottles whose weights fall outside these allowable variations. They are used in this bulletin in calculating the maximum variation in the volume of bottled foods.

To show the extent to which any allowable variation will be applicable to all bottles, it is necessary to note that the variation in the weight of hand-blown bottles is greater than that of machine-blown bottles. While this is generally an accepted fact (7), it has been further verified by 27 sets of data collected in the course of these investigations, each containing measurements on 25 to 50 bottles of 4, 8, and 12 ounce weights. It was found that the respective average deviations were 0.12, 0.24, and 0.37 ounce in hand-blown ware, and 0.03, 0.06, and 0.18 ounce in machine-blown ware. It is pertinent also to note that machine manufacture has had a steady growth. In 1912 (2) 33 factories in the United States were equipped with bottle-blowing machines. In 1913 (2) 37 factories and in 1914 (5) 54 factories, or 37 per cent of those in the United States, were so equipped. It has been estimated that 45 per cent of the bottles blown in 1917 (7, p. 129) and 60 per cent of those blown in 1918 [2] were made by automatic machines. This steady growth, together with the fact

[1] Figures in parentheses throughout this bulletin refer to the bibliography on page 20.
[2] Bureau of Chemistry surveys, unpublished.

that machine patents are now expiring, emphasizes the necessity for giving consideration to the smaller variations which may occur in machine-blown bottles.

BOTTLE FILLING.

The accuracy in bottle filling is affected by every operation of the bottler from the time he places his order for bottles until they are sealed and labeled. In placing the order the bottler has in mind, and sometimes states in his contract, the capacity which he desires. Upon receipt of the bottles the correctness of their capacity is ascertained by actual measurement, or else it is assumed that the manufacturer has delivered bottles having the capacity designated in the contract. According to the tests made the bottles are rejected or suitable arrangements are made for their use with respect to a proper declaration of quantity of contents. In a survey it was found that 10 of 16 bottling factories made tests on every lot of bottles received from the factories, and also that 10 of these bottlers did not specify in their contracts with the glass factories the capacities which they desired for their bottles. The transparent nature of the bottle compels the bottler to cater to a popular demand that the packages be reasonably full, which requires filling to a somewhat uniform height, leaving sufficient head space.

The liquid food is filled into the bottle by machines of various degrees of complexity. A general study of the catalogues of bottle-filler manufacturers has shown these fillers to fall into three general types. The first is practically a hand filler. It is equipped with a filling nozzle and a lever cut-off operated by hand. When bottles are filled to the desired filling point, as estimated by the eye or by comparison with a properly filled sample, the flow is cut off and the bottle corked. This type represents the simplest method of filling. The second type of filler works upon the siphon principle. The bottle is filled from a siphon tube connected with a constant level tank. As soon as the liquid in the bottle has reached the level of the liquid in the tank the flow ceases. The height of fill is adjusted by raising or lowering either the bottle or the delivery tube. The third type is a development of the second type in which the liquid runs into a measuring chamber of adjustable dimensions before delivery to the bottle. A uniform volume is thereby delivered into each bottle.

Of these types of fillers the second is most common. The third is used more generally for filling cans which are not transparent. Regardless of the type of machine used, the bottler is impelled to fill his bottles to a definite height in order that they may make a satisfactory appearance as a commercial article. It was found during the inspection of a number of factories that even where machines which measured the quantity to be delivered were used, continual

attention was given to the height of fill of the bottle. The short-capacity bottles, which were always too full and filled high in the neck, were partially emptied into the over-capacity bottles, which were not full enough, in order to obtain a more uniform quantity of contents.

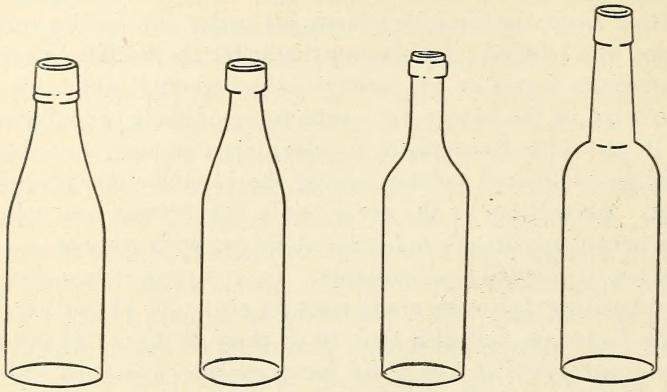

FIG. 1.—Long-necked bottles.

It is the custom of bottlers to label their products with the quantity of contents either by a paper label or by having the statement blown into the bottle. In each case the bottler must depend upon the uniformity of the bottle to secure accurate statements of the quantity of contents. This fact is considered in this bulletin in calculating the variation in volume of bottled foods.

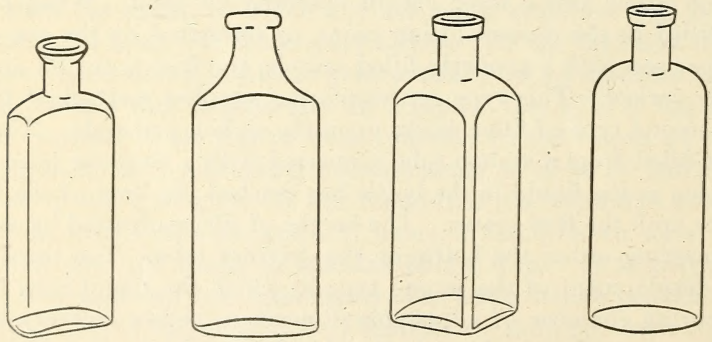

FIG. 2.—Short-necked bottles.

TYPES OF BOTTLES.

Although foods are put up in a large variety of bottles, three surveys of the industry indicate that certain types are very prevalent. In view of the mooted questions concerning the panel bottle it has not been included in this study. Figures 1 and 2 illustrate the types which have been studied. The cross section of the bottle may be

round, square, or oval, and the necks long and conical or cylindrical, or short and cylindrical. The type of shoulder shown in these figures, while of minor significance in some cases, is important in others and illustrates the type to which the data reported in this bulletin apply. It is intended that the results be applicable to the simplest and most prevalent types of bottles used for food purposes.

"GOOD COMMERCIAL PRACTICE" IN BOTTLING.

In considering the specifications which should be met by a commercial practice considered to be "good," the demands of the consumer and the law, as well as the ability of the bottler to meet the requirements, have been taken into account. Because of the transparency of the bottle, the bottler attempts to cater to the demands of the consumer that the bottle be as full as practicable, considering the necessary head space. When the bottler receives a shipment of bottles which are over capacity, he hesitates to fill the bottles with a larger quantity without changing the quantity of contents declaration on the label. On the other hand, when bottles which are under capacity are received the law demands that the contents declaration be changed to make the statement correct. If the true capacity of the bottle to the usual filling point differs only slightly from that desired, there is a possibility of making a slight increase or decrease in the height of fill. This change in the height of fill necessitates instructing a number of employees who have been trained to fill to a certain height. It also requires a change in the setting of filling machines if such are used. A further inconvenience is suffered by the necessity for the determination of the proper height of fill. A material change in height of fill, therefore, can be regarded only as a temporary expedient. It will be suffered by the manufacturer only long enough to permit him to give proper instructions to the bottle manufacturer from whom he makes his purchases. While readjustments are taking place, it is not considered that the bottler has yet attained conditions of good commercial practice.

It is evident that the first step of the bottler in eliminating his difficulties with respect to the variation in capacity of the bottles he receives is to make definite specifications in his orders. The law requires that the quantity of liquids shall be declared by volume. The height to which the bottler fills his bottles can be varied slightly, but to meet the demands of the law and the public he is required to demand of the bottle manufacturer a bottle with a definite capacity at a height of fill which will satisfy the public. This condition can be attained by inserting in the specifications in his orders the requirement that the bottle have a specified capacity at a definite height of fill. This is considered the first condition of good commercial practice.

When any lot of bottles is received, the best practice demands that they be tested. The test to be applied is whether they meet the specification as to capacity at the height of fill specified in the contract. If the bottles do not test correctly, two alternatives are possible. The bottles may be rejected or temporary expedients, such as changing the contents declaration on the labels, may be employed to use up the particular lot. Rejection of bottles involves the inconvenience of temporary loss of packages and friction with the manufacturer. It is for the bottler to decide which method will be employed. If the variation is excessive, good commercial practice would demand that they be rejected. Testing the capacity of a representative sample of each lot of bottles received and rejecting those lots with excessive variations from the contract specifications is the second step in the attainment of good commercial practice.

The testing of the bottles gives the bottler information as to his correct filling point. Whether or not the tests show a variation from his usual filling point wide enough to justify him in instructing his employees as to proper changes is a question for him to decide. The best practice would demand that the question of change of height of fill be given due consideration. The adoption of the process of making slight changes in the height of fill as indicated by the tests made on the various lots of bottles as received is the third step in the attainment of good commercial practice.

Printing labels with the quantity of contents before they are attached to the bottles is decidedly convenient. By making this statement beforehand the bottler determines the quantity of contents which he expects to fill into his bottles. The statement of quantity of contents is necessarily the same as that specified in his contract with the bottle manufacturer. The expediting of his business demands that labels be ordered before the bottles are received. There is always a possibility of altering the statement of quantity of contents by rubber stamp or by reprinting, but this is an inconvenience which will be suffered by the bottler only long enough to permit him to give proper instructions to his manufacturer to correct the capacity in the subsequent shipments. The application of labels bearing a definite, correct statement of the quantity of contents is regarded as the fourth step in the attainment of good commercial practice.

The development of good commercial practice is a growth and requires a sufficient amount of time for adjustment to proper conditions by the bottler. It involves the ordering of labels previous to the time bottles are ordered, and a requirement on the part of the bottler that his bottles be delivered to him as specified. Though this is an ideal condition and it is not conceivable that it could be continued without an occasional interruption, many factories are using this practice closely. For the purpose of this bulletin, therefore, good commercial

practice in bottling foods is the attainment of conditions in the bottler's state of business in which he (*a*) includes in his orders for bottles the specifications as to capacity when filled to a specified height, (*b*) tests a representative sample of every lot of bottles received, and rejects those lots appreciably under capacity, (*c*) fills his bottles to a height determined from the results of his tests, and (*d*) has his labels printed with a definite, correct statement as to the quantity of contents and applies them unaltered to the bottles he fills, such statement to be correct within his required variations.

The calculated maximum variations computed in this bulletin are based on the assumption that this specified good commercial practice in bottling has been attained.

CALCULATED MAXIMUM VARIATION IN THE VOLUME OF BOTTLED FOODS.

The first and most important requisite in the carrying out of the good commercial practice plan in bottling is that the variation in the bottles shall be as small as commercially practicable. With the use of accurate bottles the bottler is able to adjust his filling process to any extent he desires and to produce bottles of food which, in quantity of contents, vary within limits as narrow as he may wish to have them.

The calculated maximum variation in the volume of bottled foods is computed in this bulletin on the basis of the usual variations in the bottles. It is defined as the volume which is equivalent to the allowed weight variation of the bottle as manufactured.

Variations in the weight of bottles which the manufacturer shall allow to the blower, as published in the Wage Scale and Working Rules of the Glass Bottle Blowers' Association, are given in Table 1.

TABLE 1.—*Variations in weight of bottles allowed by manufacturers.*

Weight of bottles.	Under.	Over.
Ounces.	*Ounces.*	*Ounces.*
½ and under	⅛	⅛
[1] ½ to 1	⅛	⅛
1 to 2	¼	¼
2 to 4	¼	½
4 to 6	⅜	⅜
6 to 8	½	½
8 to 10	½	¾
10 to 12	¾	¾
12 to 14	1	1
14 to 17	1	1
17 to 20	1	1¼
20 to 25	1¼	1½
25 to 28	1½	1½
28 to 32	1½	2
32 to 40	2	3
40 to 50	3	4
50 to 60	4	5

[1] Inclusive. The following figures are not inclusive.

The variations as given in Table 1 are applicable to bottles of particular weights. While bottles of any capacity may be blown at any specified weight, if so ordered, the general practice is to follow the weights and capacities stated in the Wage Scale and Working Rules of the Glass Bottle Blowers' Association. Weights of bottles of various capacities as stated in the Wage Scale and Working Rules have been compiled in Table 2.

TABLE 2.—*Weights of bottles of various capacities.*[1]

Types of bottles.	Capacity (fluid ounces)—										
	½	1	2	4	6	8	12	16	24	32	64
	Oz.[2]	Oz.[2]	Oz.[2]	Oz.[2]	Oz.[2]	Oz.[2]	Oz.[2]	Oz.[2]	Oz.[2]	Oz.[2]	Oz.[2]
Round and fluted prescriptions	1.25	1.50	2.0	3.5	5.0	6.5	9.0	11.0	15	18	.....
Round castor oils, lemon sirups, olive oils, etc	1.00	1.50	2.25 2.5	4.0	5.0	6.5	9.5	11.0	16	20	.....
Ovals, French squares, tall blakes, and oblongs	.75	1.25	2.0	4.0	5.5	7.0	10.0	12.0	18	20	.....
Flats, short blakes, and oblongs	1.00	1.50	2.5	4.5	6.0	8.0	11.0	14.0	18	22	.....
Grape juices and catsups, champagnes, octagons, rounds, squares	.....	1.50	2.25	4.0	5.5	6.5	10.0	13.0	19	22	34
Tinctures, round and square	.75	1.25	2.0	4.0	5.0	6.5	9.0	11.5	15	18	32
Range in weight	.75– 1.25	1.25– 1.50	2.0– 2.5	3.5– 4.5	5.0– 6.0	6.5– 8.0	9.0– 11.0	11.0– 14.0	15– 19	18– 22	32– 34
Corresponding range in Table 1	½–2	1–2	2–4	4–6	4–6	6–8	8–12	12–14	14–17	17–25	32–40

[1] Compiled from text of Wage Scale and Working Rules of the Glass Bottle Blowers' Association, 1918–19.
[2] Avoirdupois.

The simple types of bottles listed in Table 2 are very common food containers. They are the types to which the results found in this bulletin are applicable. The weights of bottles of any given capacity are so uniform that they fall within one of the definite ranges in weight mentioned in Table 1. Each range in weight corresponds to a capacity. For example, a corresponding range in Table 1 of 1 to 2 ounces, avoirdupois, corresponds to a capacity in fluid ounces of 1. Therefore, there is an allowed variation in weight which corresponds to each capacity, that is, the first column of Table 1 has been converted from terms of weight to terms of capacity.

An increase in the weight of the bottle is caused by the use of more glass, which thickens the walls and decreases the capacity. Since the bottler is penalized for short capacity, the overweight limits as given in Table 1 were selected as the basis of computing the maximum variations in capacity. The overweight limits have been computed to volume equivalents by use of the factor, 1 ounce of glass is equivalent to 3.1 drams in volume, the usual factor used by glass blowers and manufacturers.[3] This factor has been further verified by measurements and computations based on the specific gravity of

[3] Bureau of Chemistry Hearing of Glass Bottle Blowers' Association, May, 1913.

glass given in literature, and is found to be sufficiently accurate for use in this bulletin. The volumes equivalent to the variations in overweight as given in Table 1 are computed by this factor and tabulated in Table 9 (page 20) under the heading " Individual bottles," opposite the various capacities given in Table 2. These are calculated maximum variations computed in this bulletin, on which further computations are based in Tables 4 and 6.

The blower is continually cautioned to " work as close to the weight specified as possible." Since those bottles which are outside the permitted variations in weight may be rejected, the blower will attempt to have them occur as seldom as possible. As a result of following this caution and attempting to keep within the limit, the weights of the bottles will be distributed in accordance with the normal law of errors. For example, if the blower intends to deliver a bottle weighing 8 ounces, most of his bottles will weigh close to 8 ounces and only a few will be over or under by large amounts. Their average weight will approximate 8 ounces and there will be about as many over as under weight. The allowable variations stated in Table 1 would probably occur very few times in the course of a day's work. These are the primary conditions for distribution according to the normal law of errors. In accordance with the principles of the law of errors, the variation of the average of the representative sample, which has the same chance of occurrence as the variation of an individual bottle, is equivalent to the individual variation divided by the square root of the number of bottles in the sample (3). In making observations of this type, it has been found that at least 50 bottles should be measured in order that the results may be accurately representative. The calculated maximum variation in the volume of a representative sample has been computed according to this rule and included in Table 9 under the column "Average of representative sample."

Data to show the possibilities of meeting these variations of the average volume are not presented in this bulletin. Studies of a similar nature (4) on other products have shown that variations computed by this method are within the range of commercial possibilities.

In the calculations of the maximum variations in Table 9 the assumption has been made that the bottler is able to limit his variations in filling to any desired degree. The figures chosen for the calculations are the weight variations allowed to hand blowers. Machine-blown bottles are more uniform in weight and also in capacity. Since the majority of the bottles are blown by machine, this calculated maximum variation is representative of the variations in the volume of bottle foods when they are packed under the specific good commercial practice conditions outlined, which require that the bottler give special attention to his methods of filling. Data are presented to show the possibilities of meeting the calculated maximum variations.

EXPERIMENTAL RESULTS.

The data which have been collected were taken for the purpose of showing the chance of occurrence of the calculated maximum variations in the capacity of the bottle and in the quantity of food therein. Other data were also collected to show the possibilities of meeting the calculated maximum variations by such temporary expedients as changing the height of fill or the declaration on the label.

VARIATION IN CAPACITY OF BOTTLES.

In order to determine the variations due exclusively to difference in the capacity of bottles, 22 representative glass factories located in Virginia, Maryland, Pennsylvania, New Jersey, West Virginia, and Ohio were visited, and 28 sets of measurements, including 1,090 bottles blown by hand and by machine processes, were taken. Certain conditions of blowing were prescribed before a set of bottles was selected for measurement. The moulds were noted to be in good repair and to have been in use at least one hour before the bottles selected for measurement were blown. It was stated that the glass was in good workable condition. All machines were operating under favorable circumstances and all blowers and gatherers were journeymen workmen. In the case of hand-blown bottles, measurements were made on a set which had been blown in a single mould. In the case of machine-blown bottles, a run of machine ware was measured. All measurements were made by pouring water from a standardized graduate into the bottles. A recapitulation of the results obtained is given in Table 3.

TABLE 3.—*Variations in capacity of bottles.*

[Data based on measurements in glass factories.]

Reference No.	Size of bottle.	Type.	Number measured.	Capacity at top.			Average deviation.	Average of average deviations of the size.
				Maximum.	Minimum.	Average.		
		HAND BLOWN.						
	Fl. oz.			*Fl. oz.*	*Fl. oz.*	*Fl. oz.*	*Fl. oz.*	*Fl. oz.*
1006–0	1	Shoo-fly flask	25	1.08	0.93	1.03	0.035	
1006–1	1	do	25	1.03	.90	.96	.032	0.033
1002–B	3	Oval prescription	25	3.55	3.31	3.47	.042	
1002–S	3	do	25	3.31	3.11	3.21	.039	
1010–1	3	do	25	3.21	2.99	3.11	.066	
1010–2	3	do	25	3.18	2.91	3.00	.055	
1001	4	Round square	50	4.77	4.33	4.52	.099	
1006–1	4	Shoo-fly flask	25	4.22	3.92	4.07	.074	
1006–2	4	do	25	4.29	3.89	4.12	.080	
1008	4	Oval prescription	50	4.66	4.19	4.48	.071	.068
1001	8	do	50	9.06	8.08	8.69	.15	
1002	8	Tall blake	50	9.19	8.25	8.62	.13	
1005	8	Soda water	50	8.92	7.67	8.32	.21	.16
1005	12	Beer	50	13.58	12.71	13.18	.15	.15
1000–K	24	Brandy	25	24.84	23.49	24.24	.30	
1000–P	24	do	25	25.69	24.17	24.71	.36	.33
1005	64	Round packer	15	68.48	66.46	67.30	.41	.41

TABLE 3.—*Variations in capacity of bottles*—Continued.

Reference No.	Size of bottle.	Type.	Number measured.	Capacity at top.			Average deviation.	Average of average deviations of the size.
				Maximum.	Minimum.	Average.		
		MACHINE BLOWN.						
	Fl. oz.			*Fl. oz.*	*Fl. oz.*	*Fl. oz.*	*Fl. oz.*	*Fl. oz.*
1004-M	2	Round packer	50	2.44	2.37	2.40	0.013	.....
1004-1	2	.....do	50	2.44	2.37	2.40	.012	.....
1004-2	2	.....do	50	2.42	2.37	2.40	.011	0.012
1004	4	Prescription	50	5.75	5.44	5.57	.068	.068
1015-A	8	Catsup	50	8.15	7.81	8.05	.06	.....
1015-B	8	Grape juice	50	8.69	8.48	8.57	.04	.....
1004	8	Oval prescription	50	9.02	8.72	8.86	.07	.....
1014	8	.....do	50	8.82	8.52	8.72	.04	.05
1004	12	.....do	50	10.75	10.48	10.65	.05	.05
1004-U	16	.....do	50	17.17	16.70	16.97	.09	.....
1004-W	16	.....do	25	17.58	17.31	17.47	.05	.07

Measurements were taken on a variety of types of bottles, the number measured in every set was usually 25 or 50, and several sets of data were usually collected on one size of bottles. The maximum, minimum, and average capacities to the tops of the bottles show the usual range of capacities. The average deviation is the average of all the variations from the average capacity of the set as measured. The average of the average deviation of the various sizes, as shown in the last column, is an index of the variation of the bottles of the size mentioned. The figures in this column are used to compute the chance of occurrence of the calculated maximum variation in the capacity of bottled foods.

The chances of occurrence of variations in a normal frequency distribution are calculated in accordance with the laws of probability as found in standard textbooks (3). The probability of occurrence of a given variation is found by the formula $f = \frac{x}{r}$, where f is a factor whose probability value is read from a table of probability integrals, x is the limiting variation whose probability of occurrence is desired, and r is the probable error of a single observation of the distribution. The complement of the equivalent of f gives the probability that variations greater than x will occur, and the resulting fraction, reduced until its numerator is one, gives the chances of their occurrence.

The variation for which it is desired to determine the chance of occurrence is the calculated maximum variation given in Table 9. This figure is given in Table 4 in the column headed "x." The probable error as found experimentally is computed from the last column of Table 3. For practical purposes, the probable error is equivalent to 0.8453 times the average deviation. It is so computed and included in Table 4, under the column headed "r." The remaining

computations in Table 4 have been made according to the method outlined in the preceding paragraph.

TABLE 4.—*Chances of occurrence of variations in the capacity of bottles larger than the calculated maximum variations.*

HAND-BLOWN.

Capacity.	Calculated maximum variation, individual bottles.	Average deviation × 0.8453.	$\frac{x}{r}$	Probability.	Chance of occurrence based on observed data.
	(x)	(r)	(f)		
Fluid oz.	*Fluid oz.*				1 in:
1	0.10	0.028	3.58	0.9842	63
4	.24	.057	4.21	.9955	222
8	.29	.135	2.15	.8530	7
12	.29	.127	2.28	.8759	8
24	.39	.279	1.40	.6550	3
64	1.16	.346	3.36	.9766	43

MACHINE-BLOWN.

2	0.19	0.010	19.00	.9999+	over 10,000
4	.24	.057	4.21	.9955	222
8	.29	.042	6.90	.9999+	over 10,000
12	.29	.042	6.90	.9999+	over 10,000
16	.39	.059	6.62	.9999+	over 10,000

While the chances of occurrence of the calculated maximum variation, 1 in 7, 1 in 8, and 1 in 3, as shown for the hand-blown 8, 12, and 24 ounce sizes, respectively, are not very large, at least the table shows that they are far from even, and indicates that there is not an unreasonable possibility that hand blowers may meet the required calculated maximum variations, in a large percentage of cases. It is also possible that further data on other types of 8 and 12 ounce hand-blown bottles might reduce the chance of occurrence of the calculated maximum variation, since these sizes include soda water and beer bottles, in which exceptional care as to exact weight is not exercised in blowing. The 24 ounce size is not exceptionally common, and a majority of the other two sizes are blown by machine.

The averages of the figures in the last column of Table 4 are 1 in 58 for hand-blown bottles and 1 in more than 10,000 for machine-blown bottles. These figures show the reliability of the calculated maximum variations when used as limits of variation in the capacity of bottles. In view of the relative prevalence of machine-blown bottles and the possibilities of exceptional care in blowing hand-blown bottles, the data indicate that only a small percentage of the bottles as they occur on the market should vary in capacity by more than the calculated maximum variations.

VARIATION IN VOLUME OF BOTTLED FOODS.

In order to determine the variation in volume of the food filled into the bottle, 27 bottling establishments located at various points

in Virginia, West Virginia, and Maryland were visited, and 20 sets of measurements, including 524 bottles, were taken. Rough measurements were first made on the bottles being used, from the result of which the bottler was given an aim in ounces by which to fill 50 bottles for measurement. The aim given was as consistent as possible with his declaration of the quantity of contents, but slight changes were often made, even though he were approximately following the good commercial practice outlined in this bulletin. The bottler was then requested to fill a number of his bottles with the specified number of ounces given to him as an aim, take the average of the distance from the top, and adjust his filling machine or filling system to fill to this average height. In cases where allowance for contraction due to change in temperature was necessary, he was instructed to deliver bottles which would be filled to this aim when cool. In cases where the bottles could not be opened, such as soda water, 50 empty bottles were selected at random, paired with full bottles, and filled to the same height by pouring water from a standardized graduate. The results so obtained were assumed to be equivalent to the volumes of food contained in the original bottles.

The results obtained are recapitulated in Table 5.

TABLE 5.—*Variation in volume of foods packed in bottles.*

Reference No.	Product.	Type of bottle.			Number measured.	Aim.	Volume found.			Average deviation.	Average of average deviations.	Average minus aim.	Average of average minus aim.
		Manufactured.	Base.	Neck.			Maximum.	Minimum.	Average.				
						Fl. oz.	*Fl. oz.*	*Fl. oz.*	*Fl. oz.*	*Fl. oz.*	*Fl. oz.*	*Fl. oz.*	*Fl. oz.*
1120	Flavoring extract.	H	Sq.	Con.....	25	0.75	0.88	0.66	0.76	0.034	0.034	0.01	0.01
1100	Soda water..	H	Rd..	Con.....	50	6.0	7.84	5.44	6.38	.29	.....	.39	.....
1110	Coca cola....	M	Sq.	Con.....	25	6.0	6.42	4.97	5.87	.27	.....	−.12	.....
1111	.....do.....	M	Sq.	Con.....	25	6.0	6.25	4.66	5.66	.25	.27	−.34	− .02
1105	.....do.....	H	Rd.	Con.....	50	7.0	7.54	6.42	7.07	.22	.....	.07	.....
1108	Soda water..	.....	Rd.	Cyl.....	50	7.0	8.18	6.12	7.34	.37	.....	.34	.....
1109	.....do.....	H	Rd.	Con.....	50	7.0	7.77	6.56	7.01	.24	.....	−.02	.....
1113	.....do.....	.....	Rd.	Con.....	25	7.5	8.69	6.15	7.28	.63	.....	−.22	.....
1101	.....do.....	H	Rd.	Con.....	50	8.0	8.38	7.54	7.97	.15	.32	−.03	.04
1114	Vinegar.....	H	Sq.	Con.....	10	15.0	15.68	14.94	15.51	.15	.15	−.51	.51
1115	.....do.....	H	Rd.	Cyl. jar..	10	20.0	20.45	18.93	19.77	.34	.....	−.22	.....
1116	.....do.....	H	Rd.	Cyl. jar..	10	25.0	26.20	25.01	25.62	.27	.....	.63	.....
1124	.....do.....	H	Rd.	Cyl. jar..	20	25.5	26.70	25.52	26.30	.19	.....	.82	.....
1104	.....do.....	M	Rd.	Cyl. jar..	20	26.0	26.87	25.69	26.29	.31	.28	.30	.38
1103	.....do.....	M	Rd.	Cyl.....	25	63.0	63.75	62.91	63.25	.19	.....	.25	.....
1117	.....do.....	H	Rd.	Cyl. jug.	10	63.0	65.61	63.75	64.25	.37	.....	1.25	.....
1123	.....do.....	H	Rd.	Cyl. jug.	19	63.0	63.24	61.22	62.22	.39	.32	−.78	.24
1102	.....do.....	M	Rd.	Cyl. jug.	20	128.0	130.70	126.82	128.02	.93	.....	.01	.....
1118	.....do.....	H	Rd.	Cyl. jug.	10	128.0	128.51	125.46	127.27	1.03	.....	.74	.....
1122	.....do.....	H	Rd.	Cyl. jug.	20	129.0	129.69	125.31	127.34	.47	.81	−1.67	− .80

With the exception of one set of data, measurements were taken on bottles of soda water and vinegar, and data were taken on hand-blown and machine-blown bottles, round and square bottles, bottles with conical and cylindrical necks, jars, and jugs. Some of these

sets were filled by hand and some by machine. The maximum, minimum, and average volumes show the range of volume. As in Table 3, the average of the average deviations of various sizes is an index of the variation in volume of food in the bottles of the size mentioned, and the figures in this column are used to compute the chance of occurrence of the calculated maximum variations in the volume of bottled foods. By computations similar to those used in Table 4, the chance of occurrence of variations in the volume of food in the bottle larger than the calculated maximum variations has been computed and compiled in Table 6.

TABLE 6.—*Chances of occurrence of variations in the volume of food in the bottles larger than the calculated maximum variations.*

Capacity.	Calculated maximum variation, individual bottles. (x)	Average deviation ×0.8453. (r)	$\frac{x}{r}$ (f)	Probability.	Chance of occurrence based on observed data.
Fl. oz.	*Fl. oz.*	*Fl. oz.*			1 in—
0.75	0.10	0.029	3.45	0.9800	50
6	.24	.227	1.06	.5254	2
8	.29	.272	1.07	.5295	2
15	.39	.131	2.98	.9556	23
20–26	.39	.236	1.65	.7342	4
63	1.16	.269	4.31	.9964	278
128	1.94	.686	2.83	.9437	18

The results of the calculations in Table 6 are given in the last column. The average of the last column is 54, showing that, as a rule, one bottle in 54 will fall without the calculated maximum variation. With the exception of the 63-ounce size, where the chance of occurrence of the calculated maximum is 1 in 278, the results indicate that there might be a frequent occurrence of variations larger than the calculated maximum variation. It should be noted, however, that soda water is perhaps the most difficult food to bottle accurately, since it is carbonated. The vinegar bottled in the establishments in which these data were collected was bottled hot, thereby giving chances for additional variation due to cooling. When it is considered that the aim of the bottler was changed in some cases from his normal height of fill, it is evident that a number of factors have been introduced to cause variation which would not be met in bottling uncarbonated liquids under conditions which have been customary for some time, as would be the case if the bottler were following the good commercial practice outlined in this bulletin. These data represent variations which would be met under very extreme and difficult conditions. Under more favorable circumstances the chances of occurrence as calculated in Table 6 would be reduced.

The average deviations given in Tables 4 and 6 afford a comparison of variations in the capacities of the bottles and variations in volume of food after filling. The deviations are compiled in Table 7 for comparison.

TABLE 7.—*Comparison of the variation in capacities of bottles with the variation in volume of the bottled food.*

Capacity of bottles.	Average of average deviations in the capacity of hand-blown bottles.	Average of average deviations of the volume of food in the bottle.
Fluid oz.	*Fluid oz.*	*Fluid oz.*
0.75	....	0.034
1	0.033	....
4	.068	....
6	....	.269
8	.16	.322
12	.15	....
16	....	.155
24	.33	.279
64	.41	.318
128	....	.811

The average deviation in the capacities of the bottles of a given size is approximately equal to the average deviation of the volume of food contained in the bottles of that size. The fact that these two deviations are practically equivalent, supports the belief that the volume variation of bottled foods is approximately equivalent to the capacity variation of the bottles themselves when blown by hand. The calculated maximum variation apparently has about the same relation to the capacity of the bottle as to the volume of food in the bottle after it is filled.

In view of the unfavorable circumstances under which the data on the volume of bottled foods have been taken and the approximate agreement with the data on the variation in the capacity of bottles, the data indicate that only a small percentage of the bottled foods on the market should vary in quantity of contents more widely than the calculated maximum variations.

RELATION BETWEEN CALCULATED MAXIMUM VARIATION AND TEMPORARY METHODS OF MEETING DECLARED VOLUME.

The calculated maximum variation is not large enough to prevent the bottler from meeting it by the two temporary methods ordinarily used, namely, changing the height of fill or changing the declaration of the quantity of contents on the label.

In the course of the investigations, capacity measurements were made on bottles from the base of the shoulder to the usual aim in filling and to the top of the bottle. It is recognized that the base of the shoulder is not a definite filling point and that measurements

will vary widely. However, the best estimate possible was made to determine this point, after which the measurements on 50 bottles were averaged. The aim, determined by the manufacturer of the bottles, was the height to which he usually fills to make his tests as to capacity. A recapitulation of the data, showing the average capacity of the bottles measured and the capacity from the base of the shoulder to the top and from the aim to the top, with their relations to the calculated maximum variations, is given in Table 8.

TABLE 8.—*Average shoulder to top capacity and head space (bottles with cylindrical necks and conical necks).*

Size.	Reference No.	Type.	Number measured.	Calculated maximum deviation.	Volume (shoulder to top).	Calculated maximum (shoulder to top).	Volume (aim to top).	Calculated maximum (aim to top).
		CYLINDRICAL NECKS.						
Fl. oz.				*Fl. oz.*	*Fl. oz.*	*Ratio.*	*Fl. oz.*	*Ratio.*
1	1006–0	Shoo-fly flask	25		0.39	0.3	0.09	1.1
	1006–1	do	25	0.10	.35	.3	.08	1.2
		Average				.3		1.2
2	1004–M	Round packer	50		.47	.4	.17	1.1
	1004–1	do	50		.47	.4	.22	1.6
	1004–2	do	50	.19	.44	.4	.11	1.7
		Average				.4		1.5
3	1002–B	Oval prescription	25		.45	.5	.33	.7
	1002–S	do	25		.37	.6	.30	.8
	1010–1	do	25		.61	.4	.21	1.1
	1010–2	do	25		.60	.4	.38	1.3
4	1001	Round square	50		.71	.3	.38	.6
	1008	Oval prescription	50		.55	.4	.16	1.5
	1004	do	50	.24	1.42	.2	.63	.4
		Average				.4		.9
8	1001	Oval prescription	50		1.19	.2	.71	.4
	1002	Blake	50		1.05	.3	.44	.7
	1004	Oval prescription	50		1.38	.2	.36	.8
	1014	do	50	.29	1.52	.2	.65	.4
		Average				.2		.6
10–12	1004	Oval prescription	50	.29	1.57	.2	.24	1.2
		Average				.2		1.2
16	1004	Oval prescription	50		2.86	.1	.36	1.1
	1004	do	25	.39	2.51	.2	.27	1.4
		Average				.2		1.3
64	1005	Round packer	15	1.61	10.65	.1	4.39	.3
		Average				.1		.3
		Grand average of individual observations.				.30		.97
		CONICAL NECK.						
4	1006–1	Shoo-fly flask	25		1.30	.2	.20	1.2
	1006–2	do	25	.24	1.35	.2	.23	1.0
		Average				.2		1.1
8	1005	Soda	50		1.87	.2	.66	.4
	1015–A	Catsup	50		2.68	.1	.19	1.5
	1015–B	Grape juice	50	.29	3.03	.1	.55	.5
		Average				.1		.8
12	1005	Beer	50	.29	3.15	.1	.78	.4
24	1000–K	Brandy	25		6.68	.6	.72	.5
	1000–P	do	25	.39	6.86	.6	.66	.6
		Average				.6		.6
		Grand average of individual observations				.25		.76

The calculated maximum variations average nearly 0.3 of the available space from the base of the shoulder to the top in cylindrical-neck bottles and nearly 0.3 in conical-neck bottles; that is, the bottler has about three times enough room in his filling range to adjust his

height of fill to meet the variations equivalent to the calculated maximum variations. The calculated maximum variations average about the same as the space in the bottle from the aim to the top, in the case of cylindrical-neck bottles and 0.8 in the conical-neck bottles (Table 8). Accordingly there is sufficient room in the bottles to permit changes from the usual height of fill to the limits of the calculated maximum variations.

The unit of change in declaration is of concern to the bottler when he receives bottles short of the capacity which he expects. It is the custom to declare the quantity of contents on bottled foods in whole units. In a survey of the bottling of flavoring extracts and similar products it was found that the prevalent sizes of bottles were 1, 2, 4, 8, and 12 ounces, 1 pint, 1 quart, ½ gallon, and 1 gallon. In bottles containing less than 2 ounces some of the declarations varied by ⅛-ounce units; in sizes from 2 to 8 ounces, some of the declarations varied by ¼-ounce units; and in sizes above 8 ounces, some varied by ½-ounce units. The calculated maximum variations for 2 ounce, 8 ounce, and 1 pint capacities are 0.19, 0.29, and 0.39 ounce, respectively, which are approximately equivalent to the usual units of declaration for these sizes of bottles. The bottler would therefore meet the variations equivalent to the calculated maximum variations if he made the usual changes in his units of declaration. It follows that the bottler's usual temporary methods of meeting the proper declared volume can be governed by the calculated maximum variations as found in this bulletin.

PRACTICAL APPLICATION OF RESULTS.

The bottler will be able to apply the results of this investigation as outlined in Table 9 to guide him in making tests on bottles received. If the capacities of the bottles at his usual filling point vary from the capacity ordered by amounts greater than the results given in Table 9, he will necessarily feel that some further steps should be taken to meet properly the requirements of the law that the volume of food declared on the labels be correct. The bottle manufacturer will be able to use the results in Table 9 to guide him in determining whether or not any shortage found in the volume of bottled food may be due to unavoidable difficulties in the manufacturing or filling of the bottles.

SUMMARY.

Good commercial practice in bottling foods has been considered in this bulletin to be the attainment of conditions in the bottler's state of business in which he (*a*) includes in his orders for bottles the specifications as to capacity when filled to a specified height,

(*b*) tests representative samples of every lot of bottles received, rejecting those appreciably under capacity, (*c*) fills his bottles to a height determined from the results of his tests, and (*d*) has his labels printed with a definite, correct statement of the quantity of contents and applies them unaltered.

The calculated maximum variations in the volume of bottled foods, as given in Table 9, have been computed from the weight variation allowed the blowers by the manufacturers, and by the use of the relation between the weight and volume of bottle glass.

TABLE 9.—*Calculated maximum variation in volume of bottled foods.*

Capacity of bottles.	Calculated maximum variation in volume.	
	Individual bottles.	Average of representative samples.
Fl. oz.	*Fl. oz.*	*Fl. oz.*
½	0.10	0.014
1	.10	.014
2	.19	.027
4	.24	.034
6	.24	.034
8	.29	.041
12	.29	.041
16	.39	.056
24	.39	.056
32	.58	.083
64	1.16	.17
128	1 94	.28

Data on the capacity of bottles and volume of food in bottles indicate that only a small percentage of the bottles of food filled in accordance with good commercial practice, as outlined in this bulletin, should vary in quantity of contents by more than the calculated maximum variations.

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